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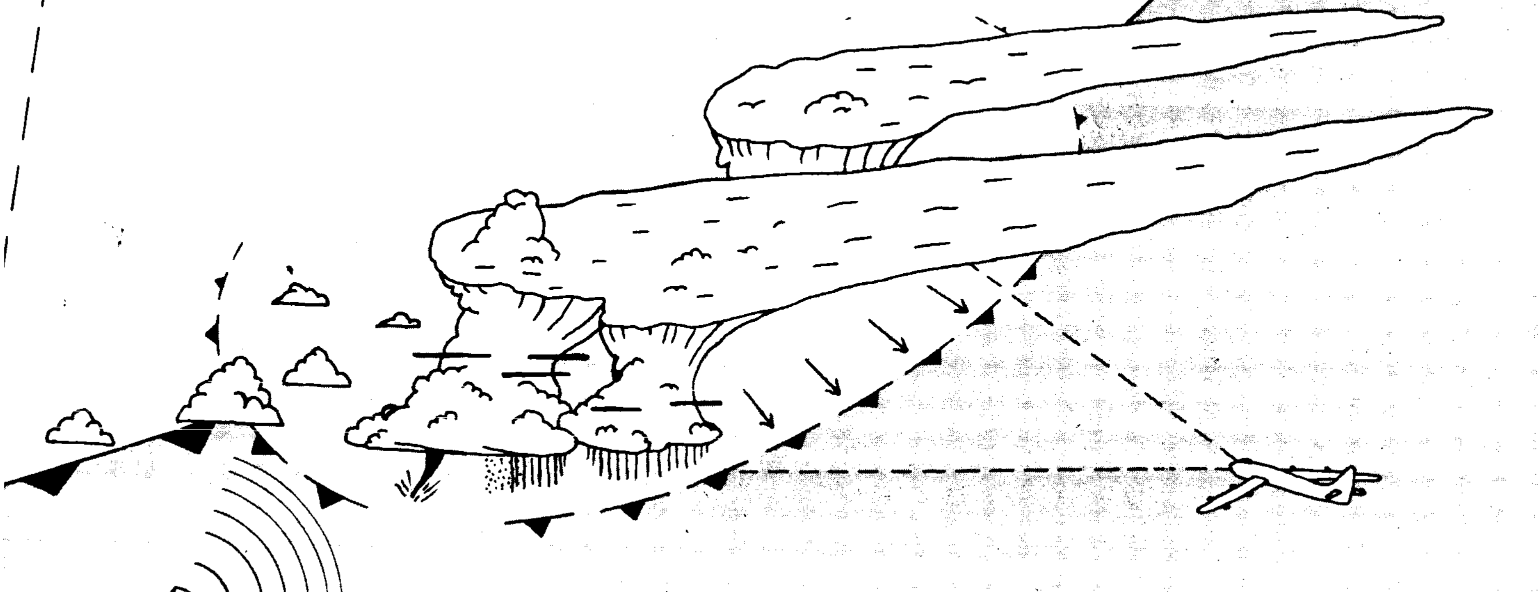
MESOMETEOROLOGY PROJECT

Department of the Geophysical Sciences
The University of Chicago

THE DECAYING STAGE OF HURRICANE ANNA OF JULY 1961 AS PORTRAYED BY TIROS CLOUD PHOTOGRAPHS AND INFRA-RED RADIATION FROM THE TOP OF THE STORM

by

T. Fujita and J. Arnold



Research Paper #28

Nov~~ember~~ 1963

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Department of the Geophysical Sciences

The University of Chicago U., Ill.

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THE DECAYING STAGE OF HURRICANE ANNA OF JULY 1961 AS PORTRAYED BY TIROS CLOUD PHOTOGRAPHS AND INFRA-RED RADIATION FROM THE TOP OF THE STORM*

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(NASA Grant NsG 333; Contract CwB WBG-6)

RESEARCH PAPER no. #28)

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* Presented before the 3rd ~~Third~~ Tech~~nical~~ Conf~~erence~~ on Hurricanes and Tropical Meteor~~ology,~~ Mexico City, ~~Mexico,~~ June 6-12 1963

ABSTRACT

Hurricane Anna is followed through its dissipating stage utilizing TIROS information and upper air data. Three orbits, two daytime (160 and 189) and one nighttime (198) on July 23, 25, and 26 respectively, were used to depict the cloud characteristics over the decaying hurricane. The outflow from the hurricane at 200 mb is examined, and comparisons are made with cloud distribution as determined by the radiation data for the individual orbits. Use is made of satellite scan geometry to determine scan characteristics and their relation to cloud interpretation.

Utilization of satellite photographs and scanning radiometer data in the tropics can be a valuable tool in the study of tropical storms. The ability of the satellite to provide useful information about the vertical and aerial extent of the cloud cover can help greatly in studying large areas on a mesoscale. When the satellite information is combined with that of other sources an excellent opportunity to study hurricane structure and dynamics on both macro- and mesoscales is available.

Hurricane Anna of 1961 formed and went through its life cycle soon after TIROS III was launched enabling most of the storm's life to be observed before the infra-red sensors underwent too much deterioration. Almost daily coverage of Anna is available from TIROS III during the period from July 14, 1961, when it appeared as an area of organized cumulonimbus activity in the intertropical convergence zone, to July 26, when the circulation about the remnant hurricane no longer was dominant enough to organize the cloud structure into a spiral structure. During the daytime orbits, 160 and 189 on July 23 and 25 and the nighttime orbit, 198, on July 26, Hurricane

Anna is observed to pass through its decaying stages. The path of Hurricane Anna prior to and during decay is shown in Fig. 1 with the hurricane positions when satellite data were utilized along the path.

The 200-mb level on all three days contained a large area dominated by the outflow from the hurricane. This rather large outflow region changed its total area only slightly during the decaying period, the main changes being a result of a system moving in from the Atlantic Ocean. At the time the hurricane moved inland the nearest edge of the outflow was 350 miles to the west from the storm center. Included on the 200-mb and 700-mb charts (Figs. 3-8) are outlines of that portion of the cloud colder than -30C, i.e., roughly cirrus, that was present at the time of the satellite observations. The cloud area enclosed by the -30C isotherm reached a maximum on the 23rd, about two days after the storm began to fill. At the time of maximum cirrus cover the cloud occupied almost 40 sq. degrees, a relatively small amount compared to the area covered by the outflow. An idea of the vertical extent of the outflow can be obtained from Fig. 2, a time cross section for Merida, Yucatan. At Merida, some 200 miles from the hurricane core, the outflow was approximately 18,000 ft deep being capped by the relatively cold tropopause. From this same cross section the horizontal extent of the outflow was estimated to be 1,400 miles.

Examination of the Channel 2 temperature analysis for these three orbits (Figs. 11, 15 and 18) reveals a marked change in the cloud temperature pattern from that as seen on July 23, Fig. 11, which is characterized by a predominance of cirrus over the still active hurricane to a situation on July 25 where the large cirrus shield has given way to a general pattern of a few cores of cumulonimbus clouds characterized by the tight gradient of the isotherms. It is interesting to note that on the 25th (Fig. 13) there are still remnants of the spiral cloud features, especially noticeable in the photograph; however, the remnant hurricane is only a weak tropical depression with maximum surface wind of 20 kt. The cumulonimbus activity on July 26 (Fig. 18) is almost twice that of the previous day, and the extent of cirrus cover has increased greatly. The slight organization that was present on the 25th had now disappeared completely. A feature worth at least passing note is the lack of any indication in the low temperature field of the clouds over Jamaica and Yucatan although it is quite apparent in the Channel 3 (Fig. 16). These clouds would be relatively low orographic cumuli.

The two sketched photographs for July 23 and 25 (Figs. 9 and 13) illustrate the banding of the cumulus by the low level wind field. This feature is especially prominent in Fig. 9 for July 23.

When considering sizes of storm systems and the cloud temperature the area that the sensor is viewing must be considered. Figures 10, 14, and 17 indicate scan-spot areas at the 20% and 50% power levels, satellite zenith angle, and scan spots on the various days with the cloud pattern determined from the temperature field of Channel 2; an estimate can be quickly made of how representative is the shape and size of a particular cloud feature. In Fig. 15 the effect of cloud elongation due to increasing zenith angles can be seen.

SUMMARY

In the case of Hurricane Anna, a well developed outflow region was present during the decaying stage. The cirrus cloud present in the storm area comprised only a small portion of the total storm outflow. For Hurricane Anna the outflow was confined to the troposphere with only small penetration of cloud towers into stratospheric air. The low-level windfield's influence on cloud structure is plain on July 23 where there is extensive lining up of the cloud rows to the north of the hurricane. The coldest cloud top temperatures were observed on July 23 while the hurricane was still well developed. The cloud top temperatures on both July 25 and 26 were about the same although the area under cloud cover increased during this period. There was a general decrease in the symmetry of the storm system with time, although two days after the hurricane had begun to decay there was still the appearance of an organized system.

It should be emphasized that the TIROS cloud pictures are well interpreted when the radiation data are used as additional information. The authors' experience revealed that the radiation data, when analysed with extreme care and accuracy, are capable of detecting cloud distribution in terms of reflectivity and equivalent blackbody temperature. The resolution near the vertical scan point is about 30 miles with the possible error in position fixes being no more than 20 miles.

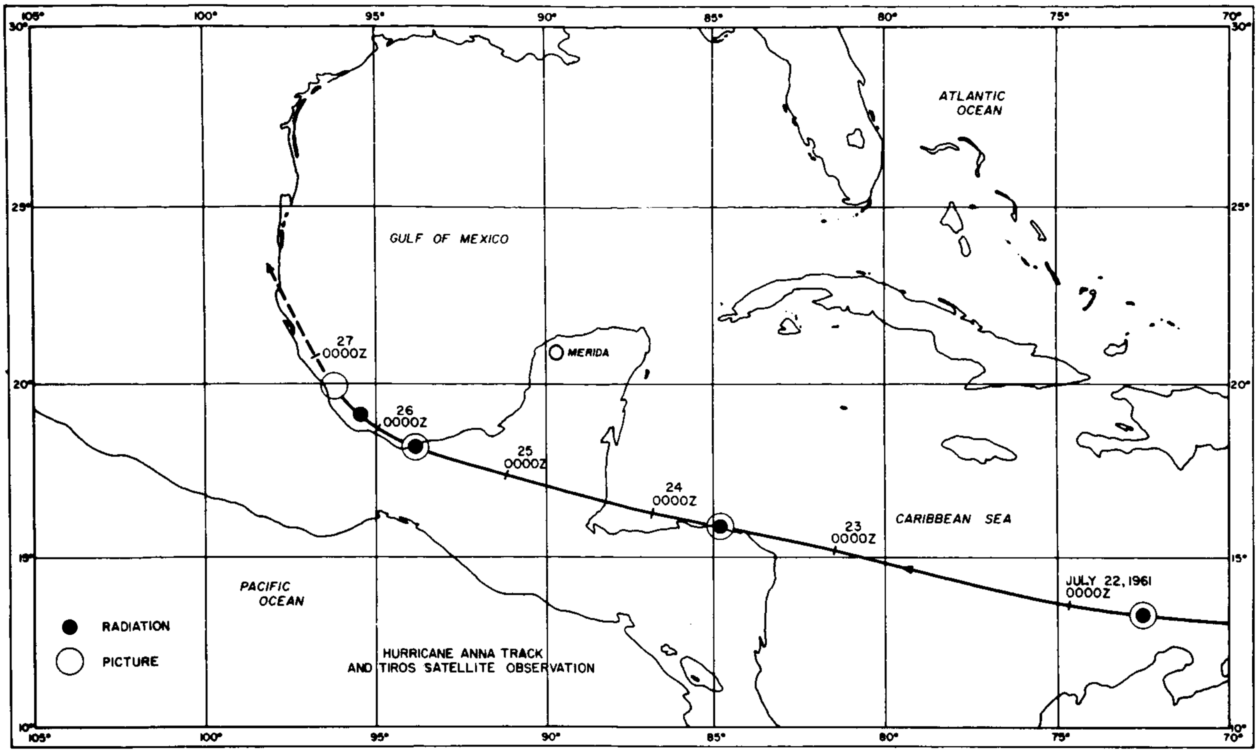


Fig. 1. Track of Hurricane Anna for the period of July 21 through July 28, 1961 including hurricane positions at which satellite data was utilized.

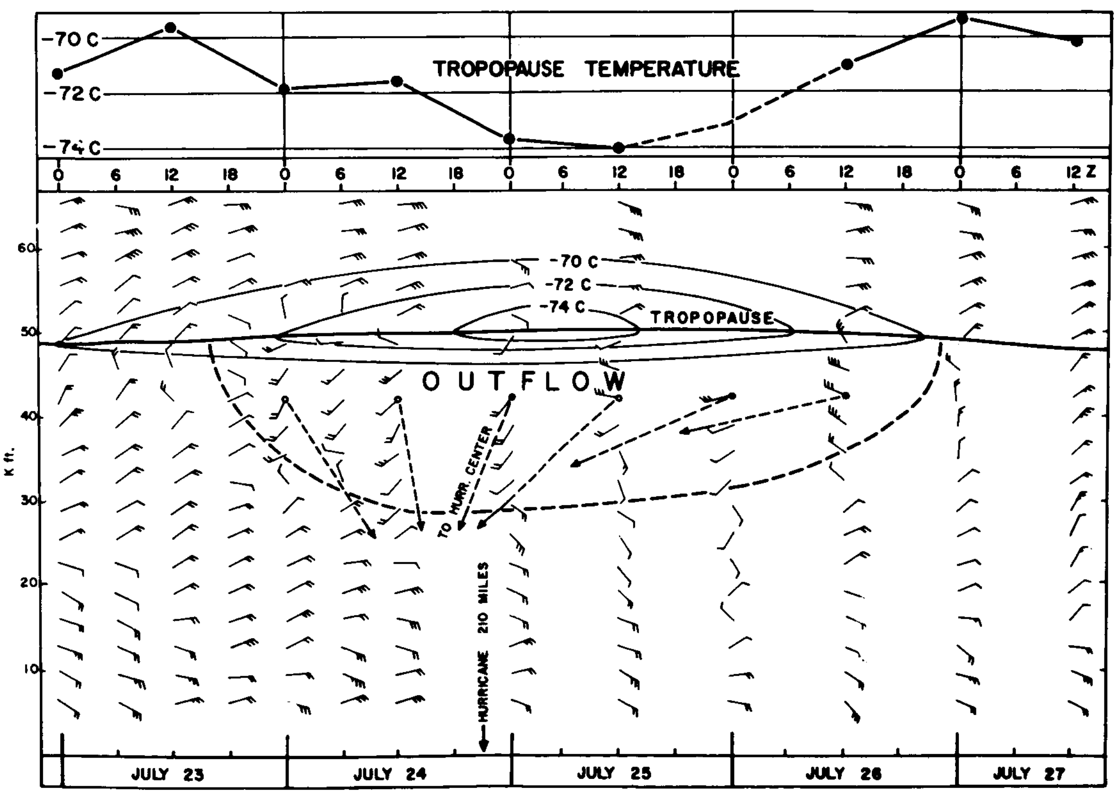


Fig. 2. Merida time cross section from July 21 to July 26, 1961 showing the vertical wind distribution, outflow from Hurricane Anna, and tropopause location and temperature. Height in 1000 feet.

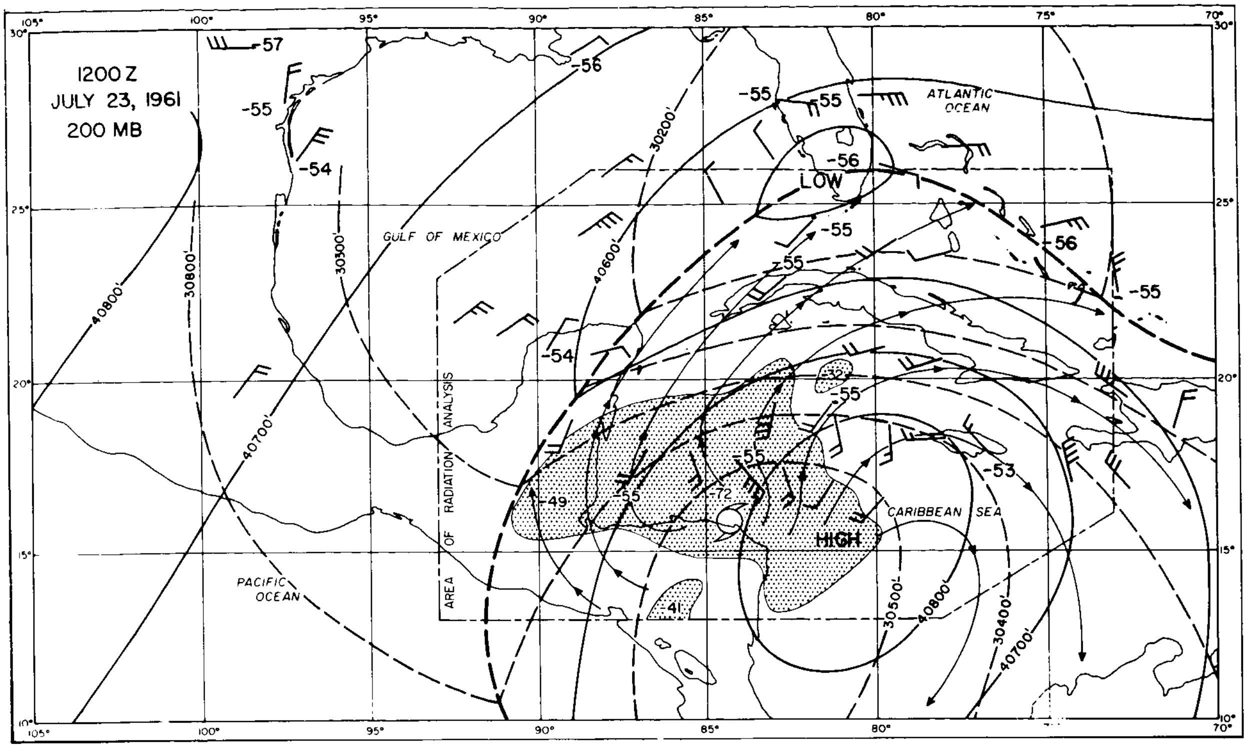


Fig. 3. 200mb map for July 23, 1961 at 1200Z showing height, temperature, wind, geostrophic wind shear between 700mb and 200mb (thickness), area of map covered by the TIROS III scanning radiometer, the outline of the cloud regions colder than -30C and the cloud top temperatures.

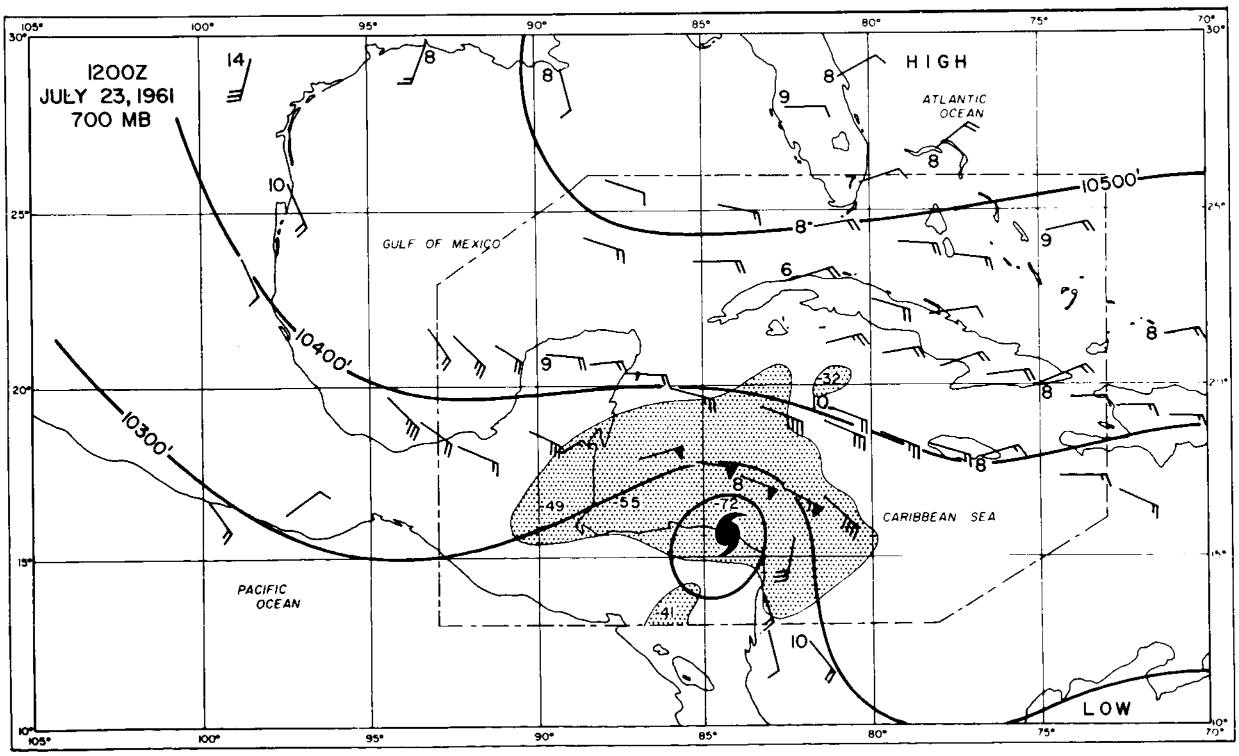


Fig. 4. 700mb map for July 23, 1961 at 1200Z showing height, temperature, wind, area of map covered by the TIROS III scanning radiometer, the outline of the cloud regions colder than -30C and cloud top temperatures.

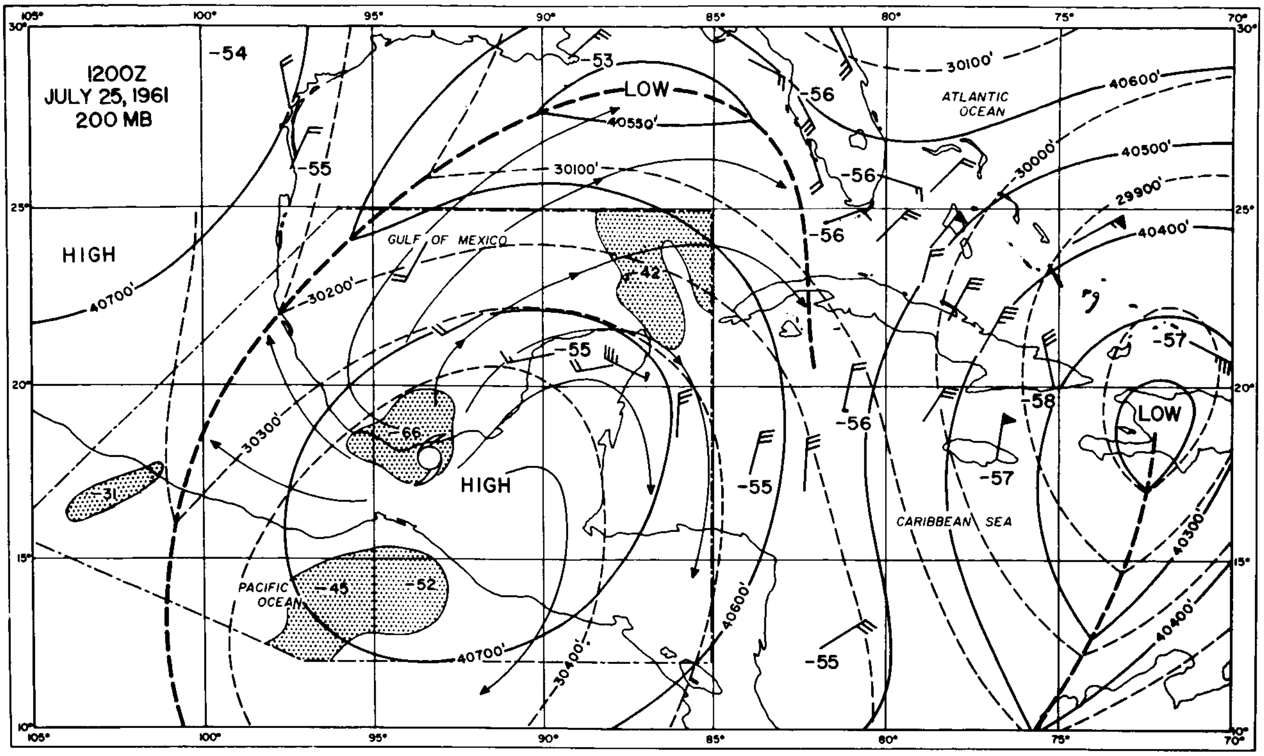


Fig. 5. 200mb map for July 25, 1961 at 1200Z showing height, temperature, wind, area of map covered by the TIROS III scanning radiometer, the outline of the cloud regions colder than -30C and the cloud top temperatures.

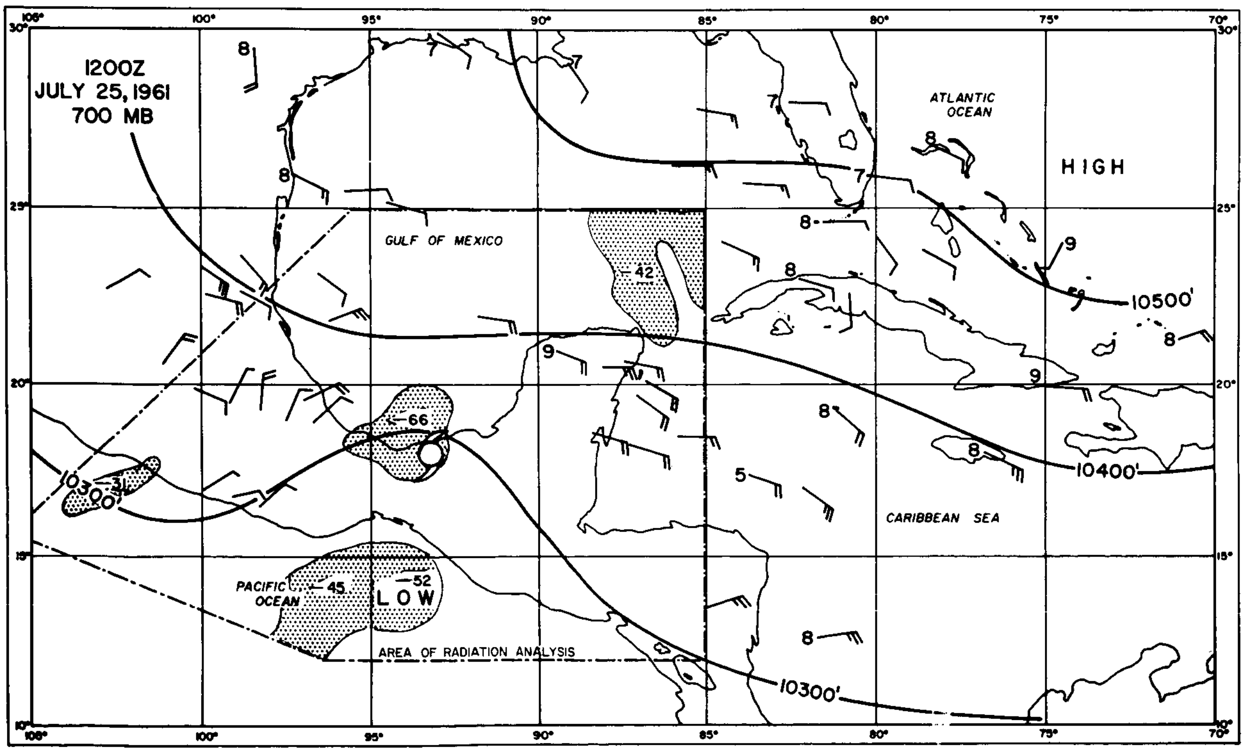


Fig. 6. 700mb map for July 25, 1961 at 1200Z showing height, temperature, wind, area of map covered by the TIROS III scanning radiometer, the outline of the cloud regions colder than -30C and cloud top temperatures.

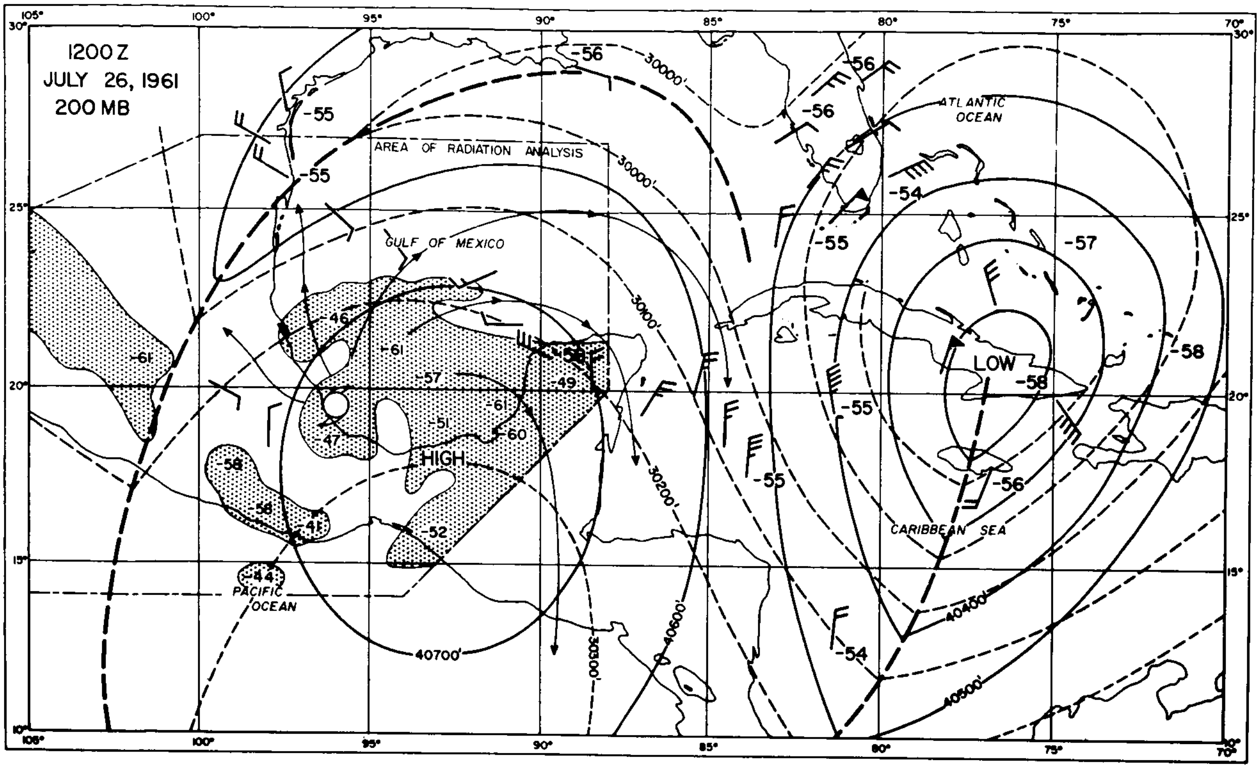


Fig. 7. 200mb map for July 26, 1961 at 1200Z showing height, temperature, wind, area of map covered by the TIROS III scanning radiometer, the outline of the cloud regions colder than -30C and the cloud top temperatures.

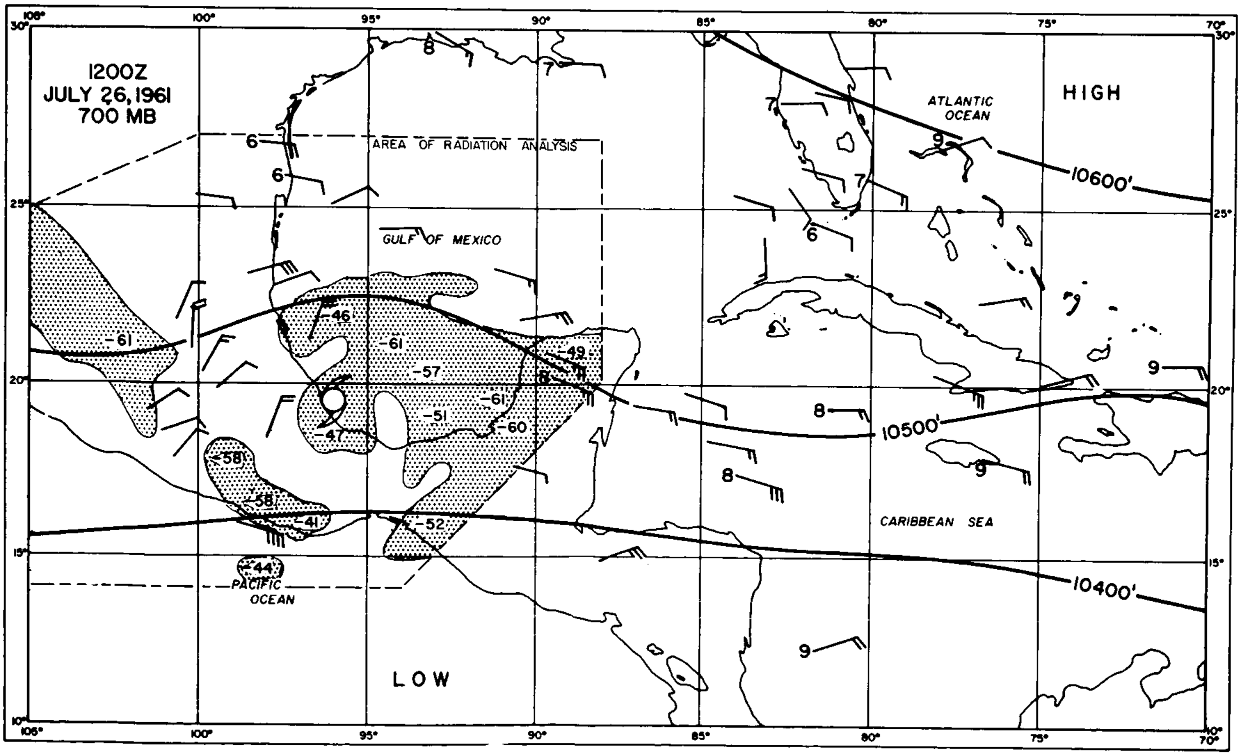
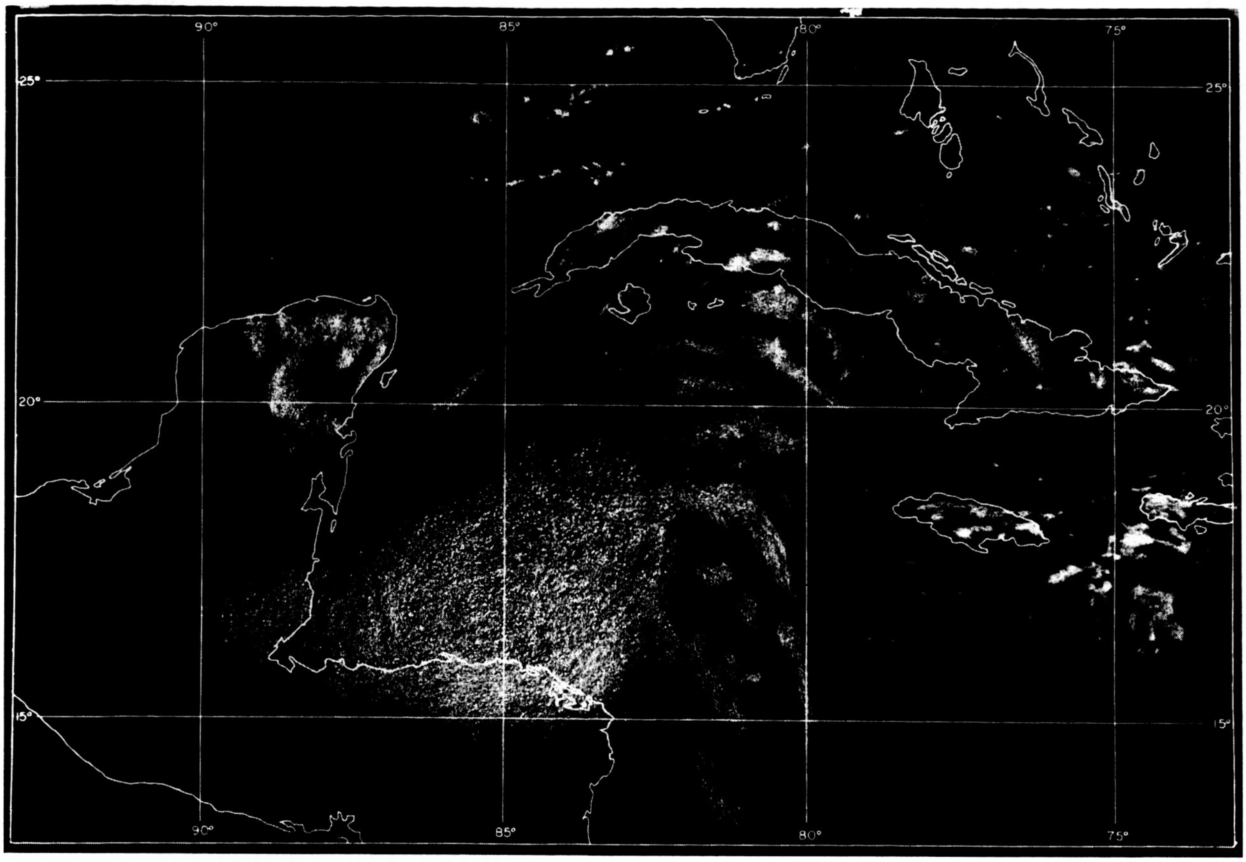


Fig. 8. 700mb map for July 26, 1961 at 1200Z showing height, temperature, wind,area of map covered by the TIROS III scanning radiometer, the outline of the cloud regions colder than -30C and cloud top temperatures.



.Fig. 9. Rectified sketch of photograph taken of Hurricane Anna on July 23, 1961.

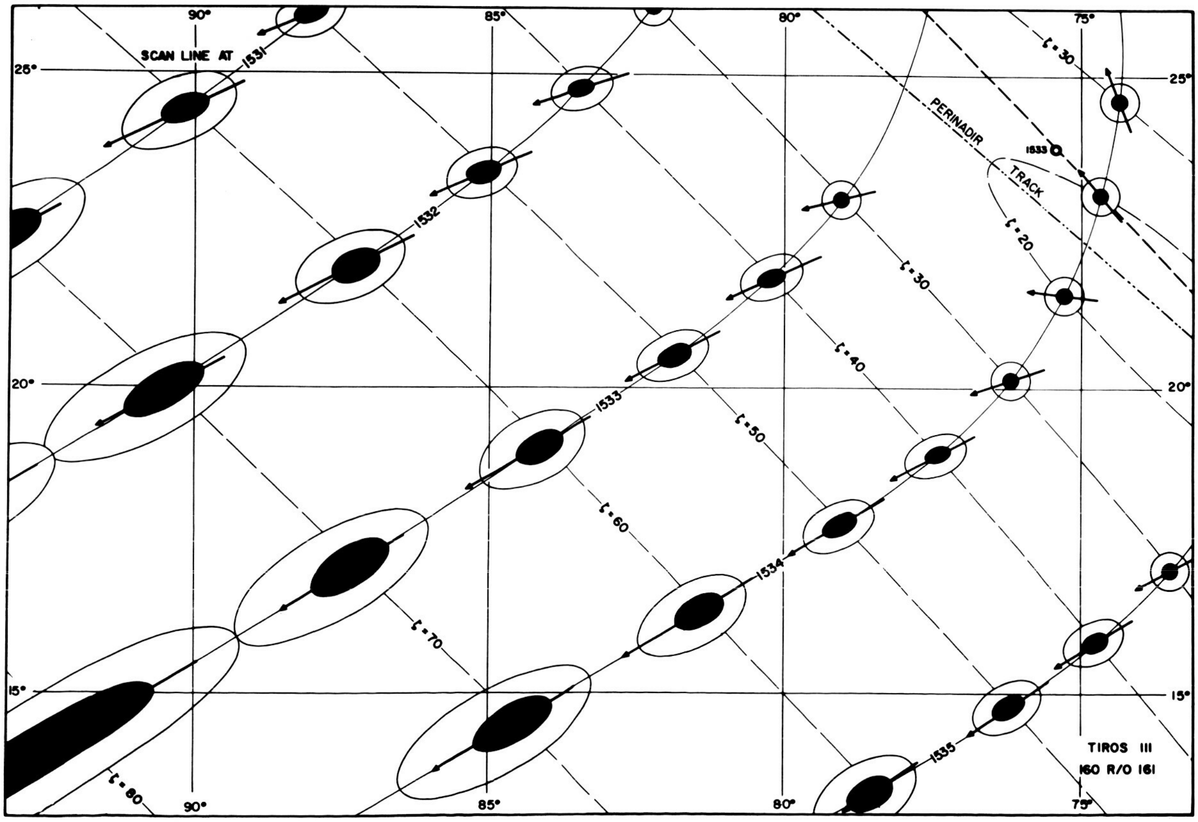


Fig. 10. Scan spots in the area of radiation analysis including 20% and 50% scan spot areas, satellite zenith angles, perinadir track and one minute scan lines.

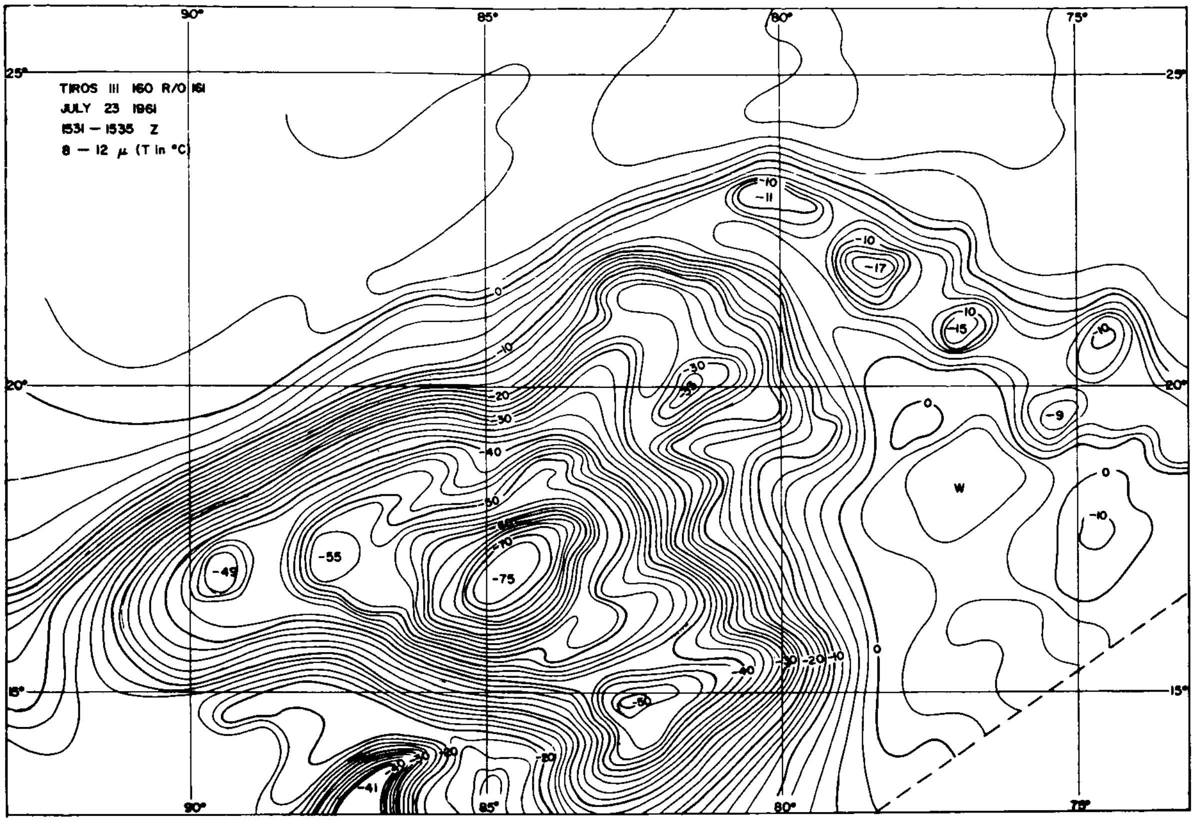


Fig. 11. Channel 2 (8 to 12 μ) analysis of equivalent black body temperature in degrees centigrade.

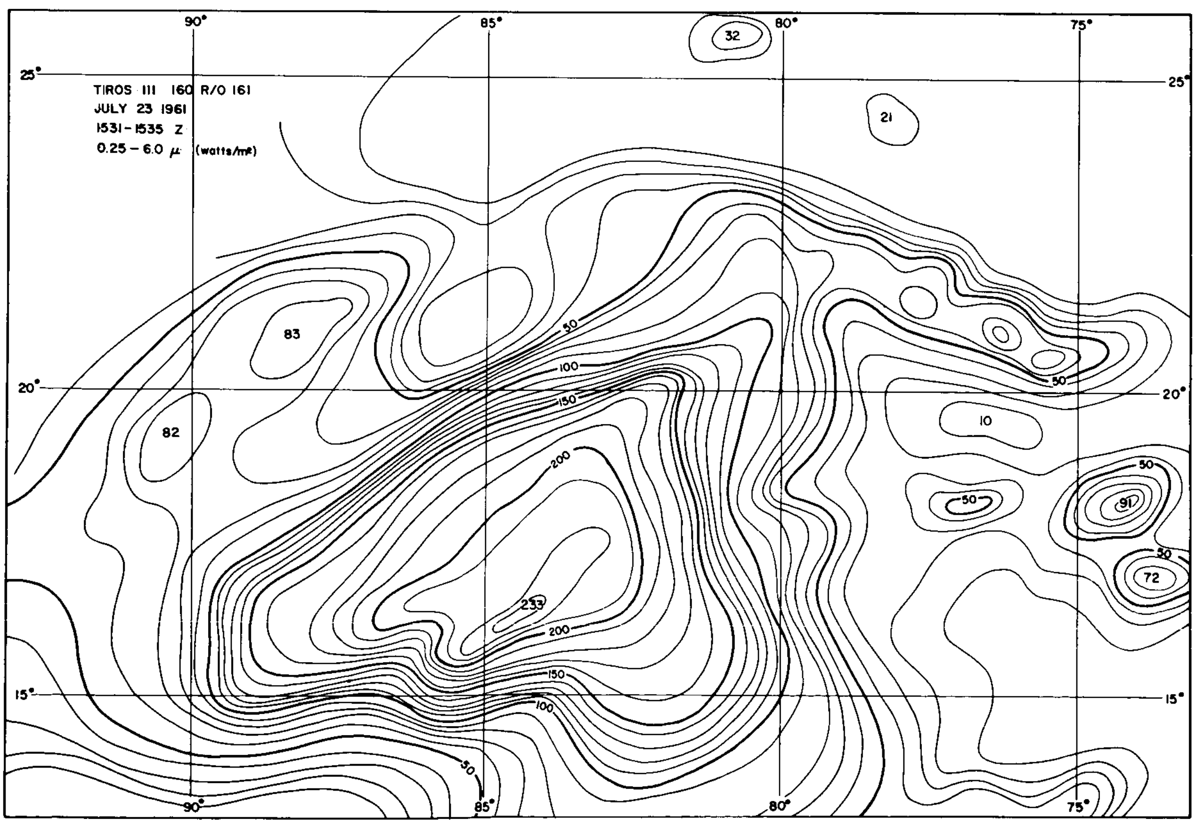


Fig. 12. Channel 3 (0.25 to 6 μ) analysis of reflected solar energy in watts per meter square.

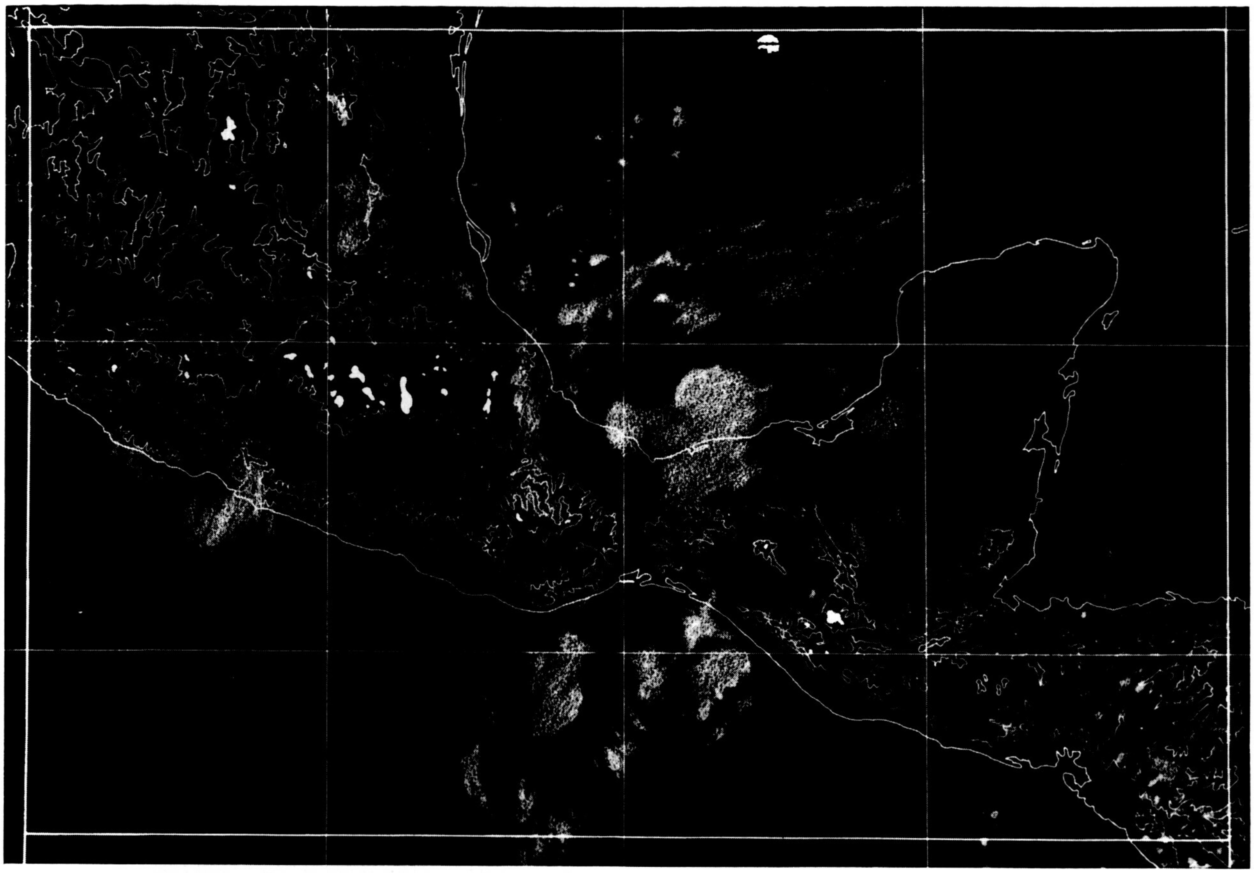


Fig. 13. Rectified sketch of photograph taken of Hurricane Anna on July 25, 1961.

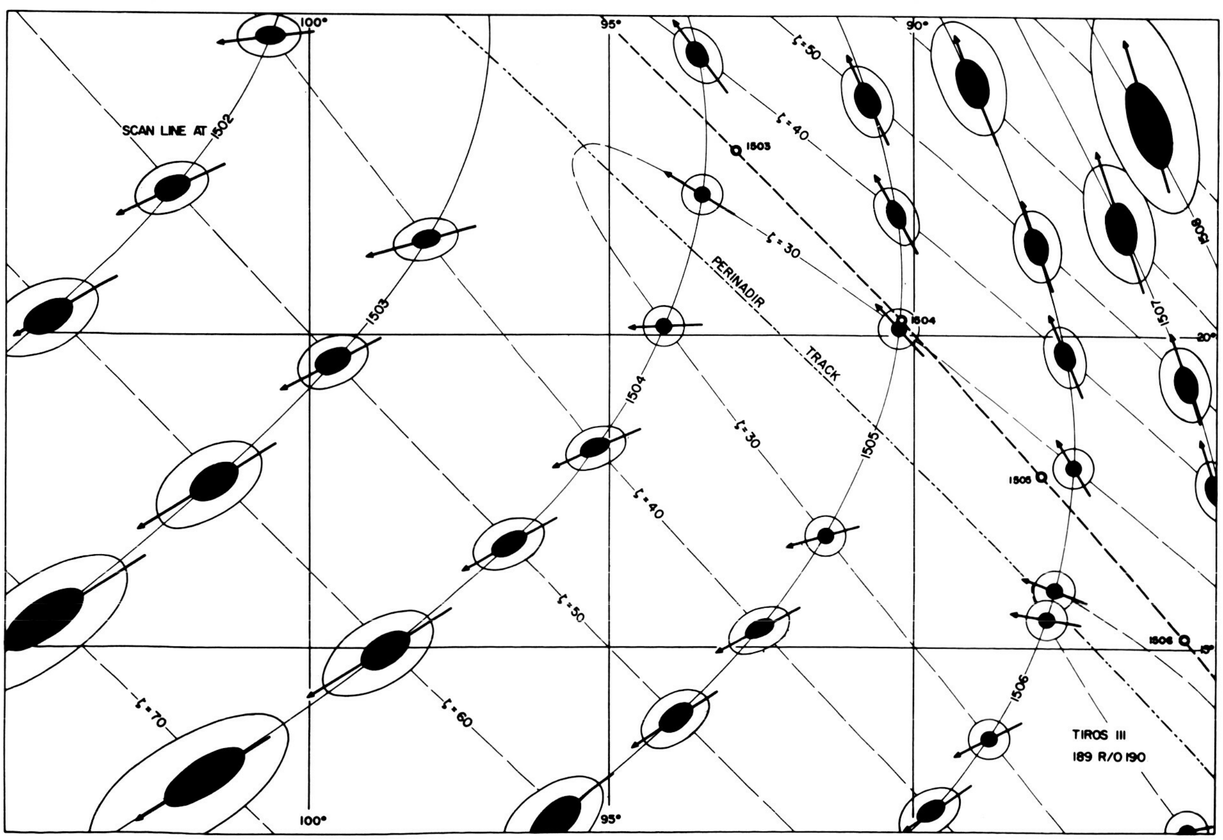


Fig. 14. Scan spots in the area of radiation analysis of July 25, 1961, including 20% to 50% power scan spot areas, satellite zenith angles, perinadir track, and one minute scan lines.

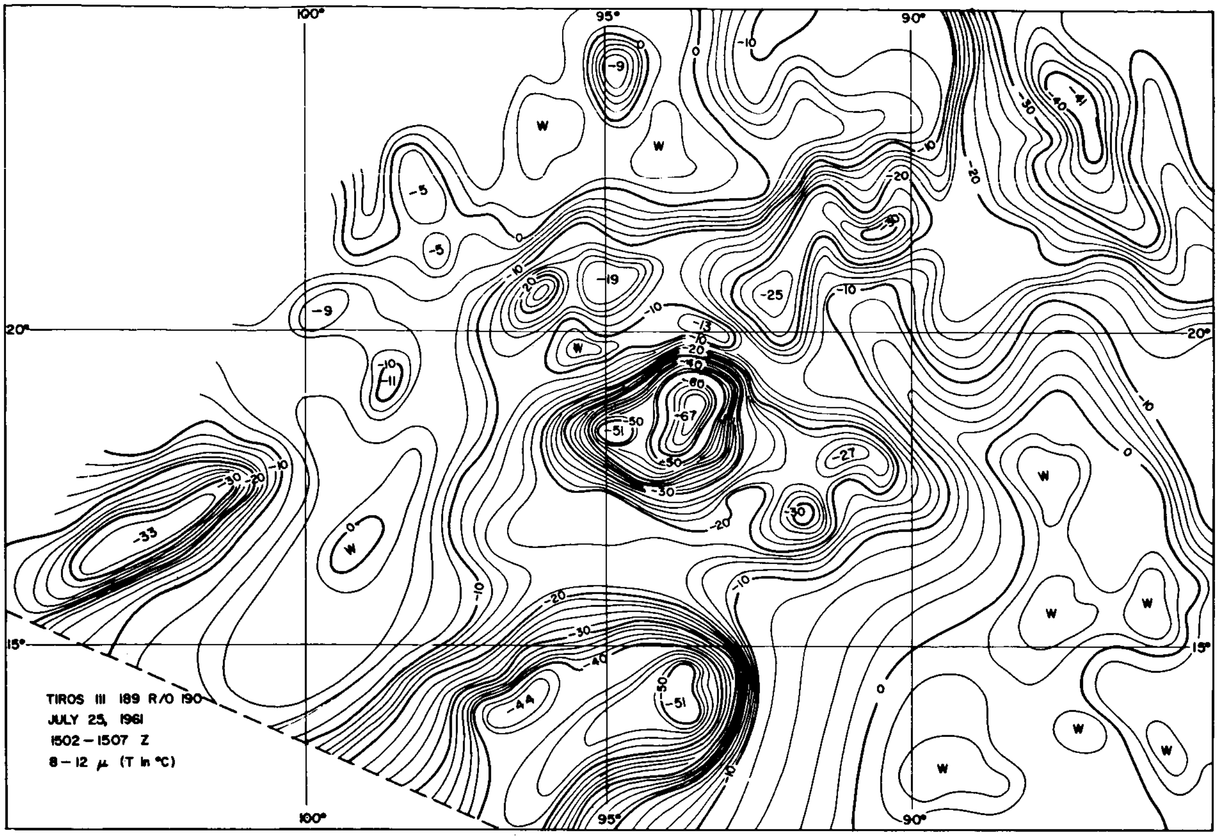


Fig. 15. Channel 2 (8 to 12μ) analysis for July 25, 1961 of equivalent black body temperature in degrees centigrade.

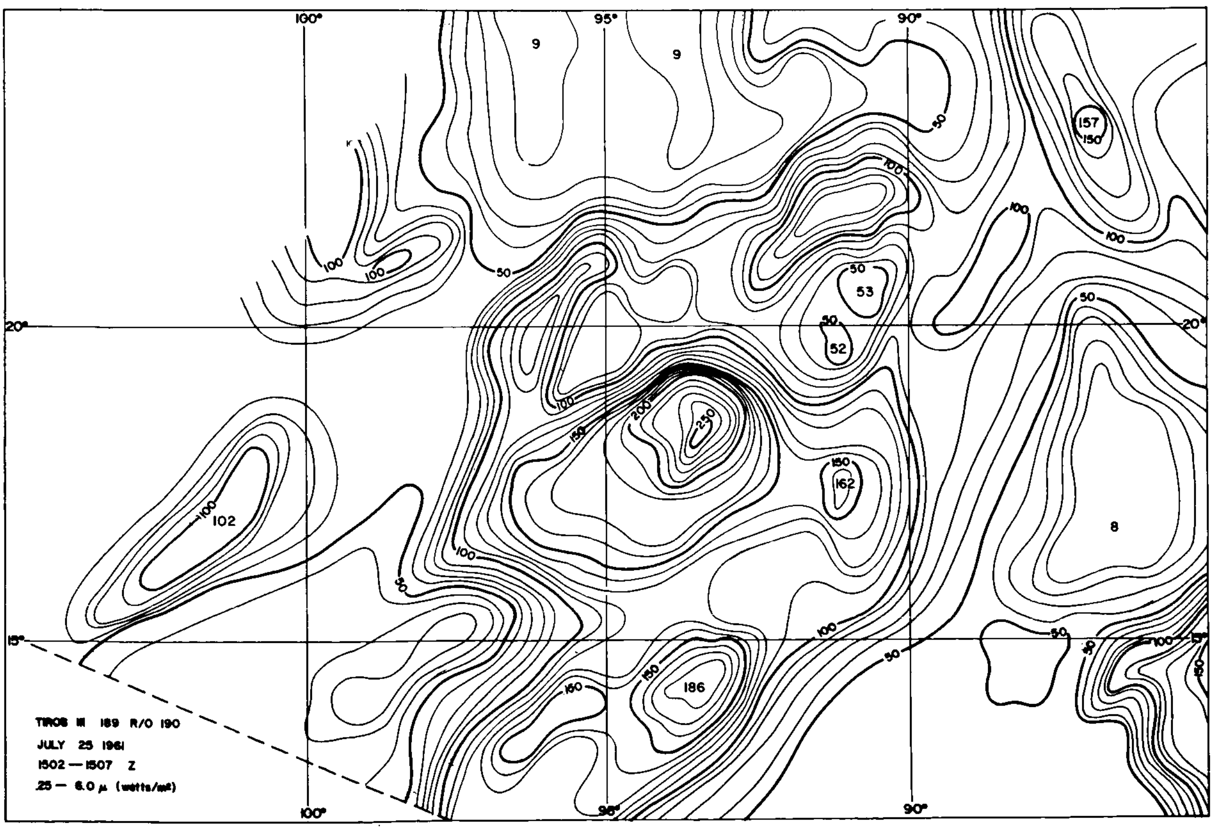


Fig. 16. Channel 3 (0.25 to 6 μ) analysis for July 25, 1961 of reflected solar energy in watts per meter square.

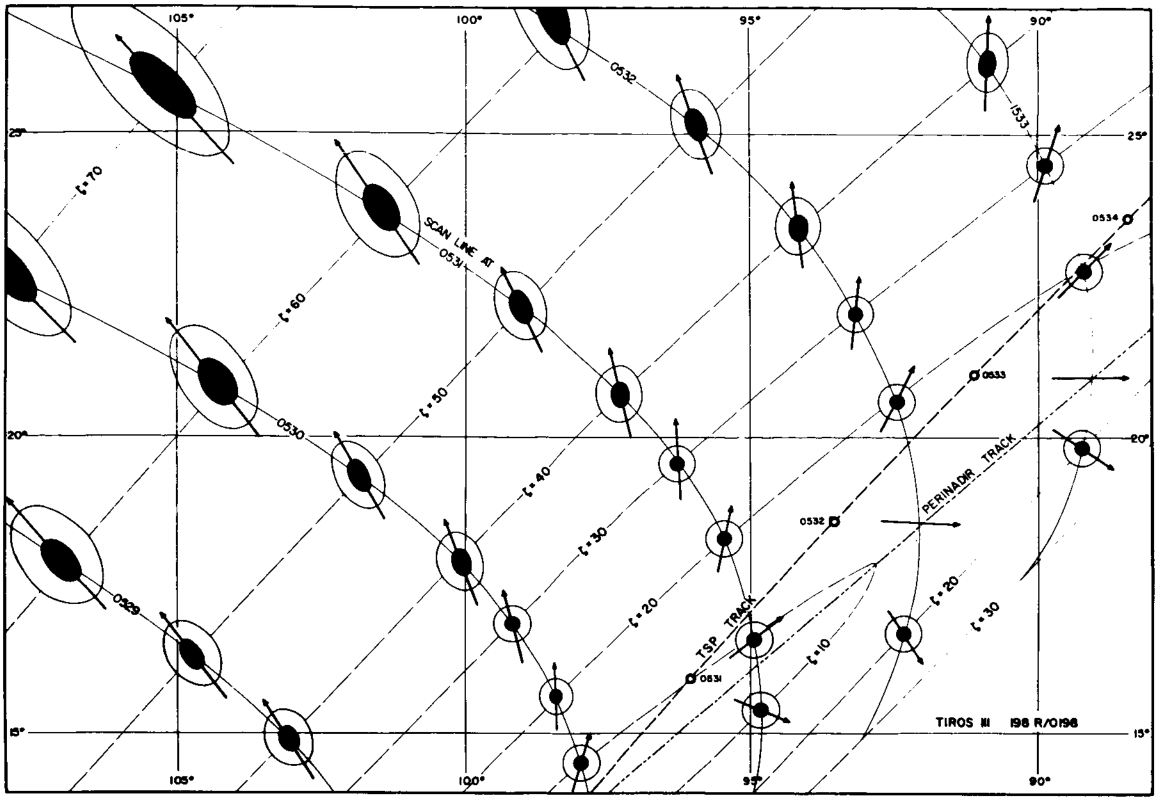


Fig. 17. Scan spots in the area of radiation analysis of July 26, 1961, 0530Z, including 20% to 50% power scan spot areas, satellite zenith angles, perinadir track, and one minute scan lines.

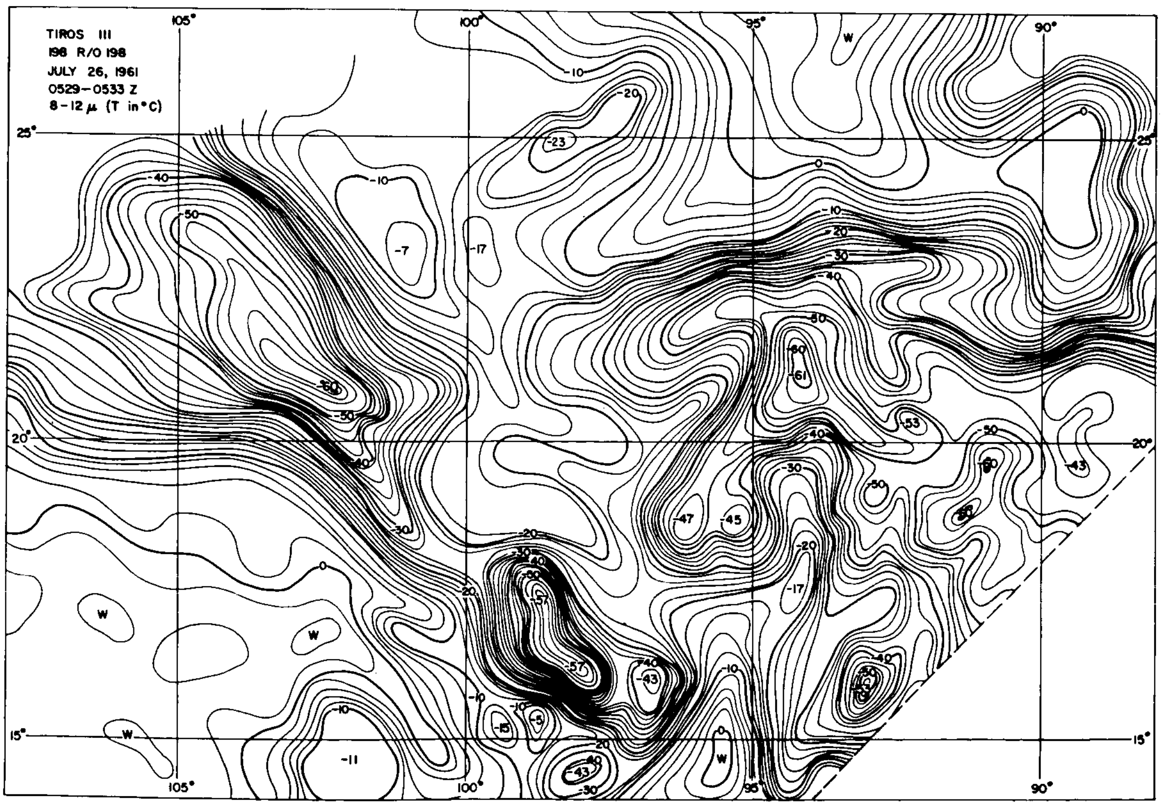


Fig. 18. Channel 2 (8 to 12 μ) analysis for July 26, 1961, 0530Z of equivalent blackbody temperature in degrees centigrade.

Fig. 19. Photograph of Hurricane Anna on July 23, 1961 at 1430Z with ten degree isotherms superimposed.

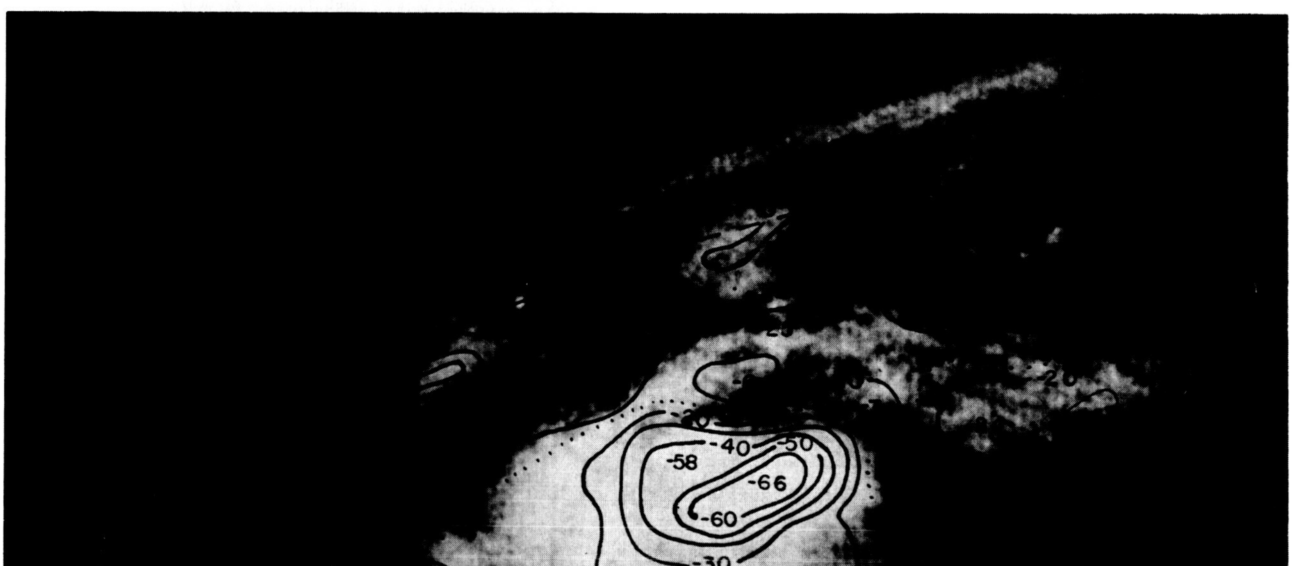


Fig. 20. Photograph of Hurricane Anna on July 25, 1961 at 1501 with ten degree isotherms superimposed.

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